

SENSITIVITY ANALYSIS OF TIG WELDING PARAMETERS FOR ASTM- 500 GRADE B WELDMENTS

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ABSTRACT

TIG welding is one of the most widely used processes in the industry. Metal deposition less distortion and bead geometry are the important parameters to justify the quality of weld. The mechanical properties of the weldment purely depend on bead geometry. The bead geometry parameters are bead width, depth of penetration and reinforcement height. The bead geometry parameters such as bead width, Depth of penetration and reinforcement height are decided according to the welding process parameters, such as welding current, gas flow rate and welding speed. So it is necessary to estimate weld process parameters to develop best bead geometry. In the present paper, mathematical models are developed using regression analysis to correlate welding process parameters to weld bead geometry which are developed with experimental investigation. The design of experiments is done using Taguchi methods. Three process parameters viz., Welding current, gas flow rate and welding speed are selected to develop the models using multiple regression analysis. The multiple regression analysis has developed curvilinear equations to predict bead geometry using a MINITAB 15, the commercial statistical program and to investigate the interaction between process parameters and bead geometry. The models are checked by using sensitivity analysis. In this paper results of experiments are used for determining the sensitivity of different process parameters of ASTM- 500 Grade B elements.

KEYWORDS: Taguchi Method, Welding Parameters, Welding, TIG Welding and Sensitive Analysis.

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INTRODUCTION

Tungsten Inert Gas welding is widely used welding process in industrial applications. Quality of weld depends on the input welding parameters. The behavior of weld bead is predicted based on input parameters of the process and are considered for better weld. The primary adjustments in any welding operation can possible and helpful for good weldments. For better bead geometry different ranges are considered for the analysis and to develop better bead geometry. Proper filler rod is selected such that the base metal is compatible to filler rod. Optimal current, welding speed and Gas Flow Rate has to be identified in order to get better defects free joint.

Taguchi's Design Method

Based on variance parameter of statistical method, Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan the optimum setting of input parameters, which uses the orthogonal arrays to confirm control input parameters. The signal to noise ratio is also developed by the same which works on logarithmic function which decides the way of doing the work with larger signal to noise ratio.

Level Orthogonal Array

Orthogonal array helps to develop the experimental design. it consists of arrangement of process parameters and for development of weld responses. The orthogonal array helps to estimate the process with defined levels at each parameters.. Table 1 details the L9 orthogonal array design of experiments.

Table 1: Orthogonal Array

Exp. No.	Process Parameter		
	Welding Current	Welding Speed	Gas Flow Rate
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

TIG welding is one of the most popular welding methods, especially in industrial environments due to the wide range of weldable metals, low in cost, high level of productivity and easy to learn. It is also popular in robot welding, in which robot handles the work pieces and the welding gun to quicken the manufacturing process. Different types of materials are most likely done by TIG welding Process especially aluminum and magnesium and extended to stainless steel and steels also. It is mostly suitable for industrial application. GTA welding also called as TIG welding named as Tungsten inert gas welding. Tungsten electrode is non consumable. Filler metal is added into the molten pool. at the edge the filler metal is dipped for the weld and to prevent oxidization inert gas flows out of the welding torch. the shielding is done to protect from oxygen in the atmosphere. This method is good for 0.25 inch thick plates. The travel speed is governed properly to have better weld bead. The advantage of tig welding gives better appearance and ease of finishing. The TIG welding is used in food industry, air craft industry, nuclear industry, maintenance and repair work etc. It consists of power source, a shielding gas and a TIG hand piece. The arc is then created between the tungsten electrode and the work piece. Shielding gas is used to protect from the surroundings. Required heat is produced due to electric arc.

Working of TIG Welding

Arc is established between a tungsten electrode and the work piece. The process of making is kept in an inert atmosphere (Ar, He, or Ar-He mixture). Filler metal is added to complete the process and it is usually depends on thickness of plates to be welded. Automatic or manual process is adopted to filler material.AC currents are used for welding from power source. High quality welding of different materials can done by TIG welding process. This process is mainly suitable for Stainless Steel, Titanium and Aluminium.

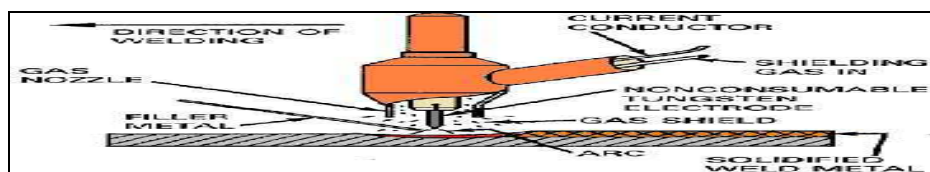


Figure 1: TIG Welding Process

The arc is struck from a electrode to the work piece and metal has been trasfered from electrode, and finally

formed as a molten pool. The tungsten electrode is used because of high melting point. Inert gas shields the entire process of making the weldment. The process is shown in Figure 1

Table 2: Mechanical Properties of Grade B material

Tensile Strength Ultimate (MPa)	Tensile Strength yield(MPa)	Elongation at break (%)	Bulk Modulus(GPa)	Shear Modulus(GPa)
400	315	23.0	140	80.0

Table 3: Chemical Composition of Grade B material

Carbon, C	Copper, Cu	Iron Fe	Phosphorous P	Sulphur
<0.30%	<0.18%	99%	<0.050%	<0.0630%

TIG welding is best suited for fabrication of ASTM 500 Grade B metals. The mechanical properties and its chemical composition are shown in Table 2 and 3.

Applications

High quality welds are prepared by TIG welding with low equipment cost. It is mainly used for aerospace and nuclear industries. And also used for small jobs, maintenance and repair work which has a facility for easy control, but it requires high skill to operator. It is used in manual, semiautomatic and automatic.

LITERATURE REVIEW

Ugur Esme [1] electrode forces with experimental study done on resistance spot weld. K. Kishore, P. V. Gopal Krishna, K. Veladri and Syed Qasim Ali [2] worked on welding on different materials like steel and other steel Grades.. Sourav Datta, Ajay Biswas, Gautam Majumdar [3] worked on sensitivity is analyzed using optimum input process parameters. P K Palani, Dr N Murugan[4] use of Design of experiments for experimental investigations. [5,6] process parameters with levels are defined using orthogonal array. S.P. Gadewar et al. [7] investigations are done on SS304 with mechanical strength.. N.Lenin et al. [8] optimized the optimization on dissimilar metals..Kishore et al. [9] process characterization on AA 6351 using TIG welding was analyzed..ANNOVA method is used for the same. Ugur Esme et al. [10] works on multi objective optimization using Grey relational co-efficient.it uses HAZ and tensile strength using ANNOVA techniques to optimize the process. Bandhita Plubin et al. [11] worked on FRAW for the ST37 steels with tensile strength as output parameter. T.Senthil Kumar et al. [12] discusses the corrosion effect on welds using pulse frequency as stated parameter and analyzed with ANNOVA for aluminum alloys. Different mathematical relations are used to find the optimum parameters for the corrosion pitting minimization Ahmed Khalid Hussain et al. [13] studied the behavior of tensile strength characterization with process parameters on welded joints in GTAW process of aluminum alloys.. L.Suresh Kumar et al. [14] discussed on the austenitic stainless steel AISI 304 and 316 mechanical properties on welding. This process is done on TIG and MIG welding process. Voltage is dominant parameter for the process conditions and also analyzed the HAZ. Farhad Kolahan et al. [15] discusses on mathematical model of welding on gas pipelines. Orthogonal array for design of experiments is used. ANNOVA also used for checking the data adequacy.

METHODOLOGY

Taguchi experimental design method is used for the experimentation process. (L9) orthogonal arrays with three columns a procedure. Taguchi method can study data with minimum experimental runs. In this paper, the design of

experiment work can be decided by this method. According to the experiment conditions in TIG welding process for weld bead, the number of level settings and their levels by welding for each process parameter Based columns and nine rows was employed.

Table 4: Process Parameters and their Levels for TIG Welding

Parameter	Symbol	Low	Medium	High
Welding current(Amp)	I	240	260	280
Welding speed(mm/min)	S	40	45	50
Gas flow rate(lit/min)	G	10	12	14

Using the experimental results obtained from the least squares regression, analysis based on bead geometry the mathematical modeling for the parameters are detailed below.

$$\text{Bead Width (BW)} = -0.19 + 0.0696I + 0.529S - 0.165G - 0.000101I^2 - 0.0054S^2 + 0.0175G^2 + 0.000005IS - 0.00101IG$$

$$\text{Depth of penetration (DP)} = 69.1 - 0.304I - 0.751S - 2.13G + 0.000492I^2 + 0.00873S^2 + 0.0429G^2 - 0.000006IS + 0.00493IG$$

$$\text{Reinforcement height (RH)} = 12.9 - 0.0340I - 0.5988S + 1.42G + 0.000187I^2 + 0.00600S^2 + 0.00250G^2 + 0.000002IS - 0.00576IG$$

Where I=Current (Amps), S= Welding Speed (mm/min), G= Gas flow Rate (lit/min.)

The sensitivity of the process is obtained by differentiating the responses with respect to input parameters and the equations for the responses are detailed by substitution of values given below.

Bead Width (BW) =

$$\frac{\partial W}{\partial I} = 0.696 + 0.529S - 0.165G - 0.000202I - 0.0054S^2 + 0.0175G^2 + 0.000005S - 0.00101G$$

$$\frac{\partial W}{\partial S} = 0.529 + 0.0696I - 0.165G - 0.000101I^2 - 0.0108S + 0.0175G^2 + 0.000005I - 0.00101G$$

$$\frac{\partial W}{\partial G} = -0.165 + 0.0696I + 0.529S - 0.000101I^2 - 0.0054S^2 + 0.035G + 0.000005I - 0.00101I$$

Depth of Penetration (DP) =

$$\frac{\partial D}{\partial I} = -0.304 - 0.75S - 2.123G + 0.000984I + 0.00873S^2 + 0.0429G^2 - 0.000006S + 0.00493G$$

$$\frac{\partial D}{\partial S} = -0.75 - 0.304I - 2.123G + 0.000492I^2 + 0.01746S + 0.0429G^2 - 0.000006I + 0.00493IG$$

$$\frac{\partial D}{\partial G} = -2.13 - 0.304I - 0.75S + 0.000492I^2 + 0.00873S^2 + 0.0858G - 0.000006IS + 0.00493I$$

Reinforcement Height (RH) =

$$\frac{\partial H}{\partial I} = -0.0340 - 0.5988S + 1.42G + 0.000374I + 0.00600S^2 + 0.00250G^2 + 0.000002S - 0.000576G$$

$$\frac{\partial H}{\partial S} = -0.05988 - 0.0340I + 1.42G + 0.000187I^2 + 0.0120S + 0.00250G^2 + 0.000002I - 0.000576IG$$

$$\frac{\partial H}{\partial G} = 1.42 - 0.0340I - 0.5988S + 0.000187I^2 + 0.00600S^2 + 0.0050G + 0.000002IS - 0.000576I$$

RESULTS & DISCUSSIONS

By keeping speed as constant and calculating the values of sensitivities at different currents, gas flow for bead width, depth of penetration and reinforcement height are computed and detailed in Table 5 to 6

Table 5: Sensitivities of Process Parameter on Bead Width (When Speed =45 mm/sec)

Current (Amps) (I)	Gas Flow Rate(lit/min) (G)	$\frac{\partial W}{\partial I}$	$\frac{\partial W}{\partial S}$	$\frac{\partial W}{\partial G}$
240	10	12.98327	8.6066	23.753
	12	13.42125	8.5618	23.823
	14	13.99923	8.6570	23.893
260	10	12.97923	8.7867	2.93114
	12	13.41721	8.7015	3.00114
	14	13.99316	8.7563	3.07114
280	10	12.97316	8.8860	24.4048
	12	12.90210	8.7604	24.4748
	14	13.98912	8.7748	3.1203

Table 6: Sensitivities of Process Parameter on Depth of Penetration (When Speed =45 mm/sec)

Current (Amps) (I)	Gas Flow Rate(lit/min) (G)	$\frac{\partial D}{\partial I}$	$\frac{\partial D}{\partial S}$	$\frac{\partial D}{\partial G}$
240	10	-49.01098	-49.76454	-61.61835
	12	-51.37352	-49.77054	-61.60119
	14	-53.39286	-49.43334	-61.58403
260	10	-49.06028	-49.93866	-61.91295
	12	-51.35384	-49.74746	-61.74135
	14	-53.60344	-49.21306	-61.56975
280	10	-49.21959	-49.71918	-62.58615
	12	-51.700453	-49.33078	-62.41455
	14	-37.44308	-48.59918	-62.2495

Table 7: Sensitivities of Process Parameter on Reinforcement Height (When Speed =45 mm/sec)

Current (Amps) (I)	Gas Flow Rate(lit/min) (G)	$\frac{\partial H}{\partial I}$	$\frac{\partial H}{\partial S}$	$\frac{\partial H}{\partial G}$
240	10	-0.34775	3.17888	-12.0756
	12	2.59073	3.36408	-12.1196
	14	-5.38621	3.56928	-12.1186
260	10	-11.27547	3.21692	-12.914
	12	2.59821	3.17172	-10.989
	14	5.55669	3.14652	-10.979
280	10	-0.33279	3.40456	-9.7728
	12	2.60569	3.12896	-9.7628
	14	5.56417	2.87336	-9.7528

The sensitivity of bead width, Depth of penetration and Reinforcement height are plotted with calculated values and are detailed in figure 2 to 10

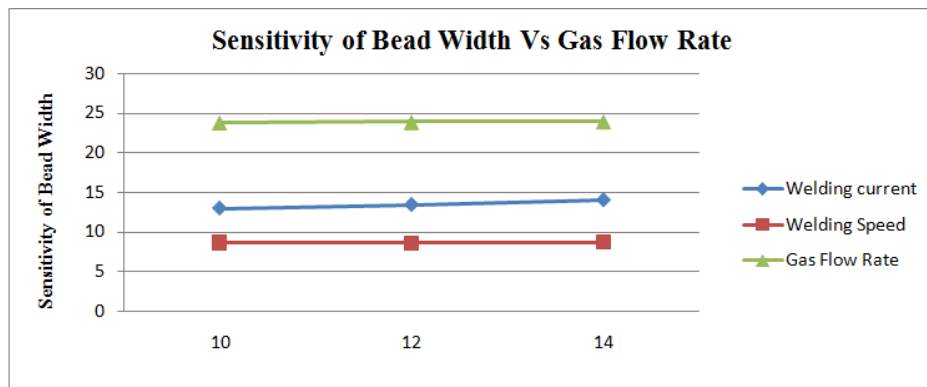


Figure 2: Shows Sensitivity of Bead Width Vs Gas Flow Rate (When Current=240 amps, Welding Speed=45mm/sec)

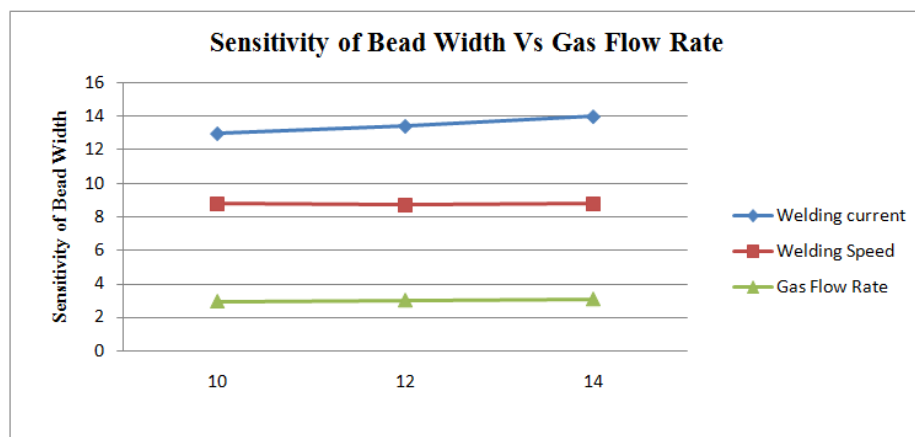


Figure 3: Shows Sensitivity of Bead Width Vs Gas Flow Rate (When Current=280 amps, Welding Speed=45mm/sec)

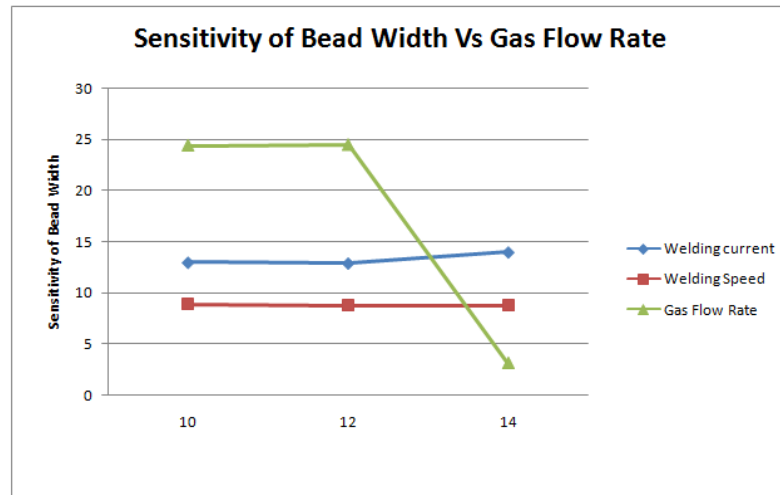


Figure 4: Shows Sensitivity of Depth of Penetration Vs Gas Flow Rate (When Current=260 amps, Welding Speed=45mm/sec)

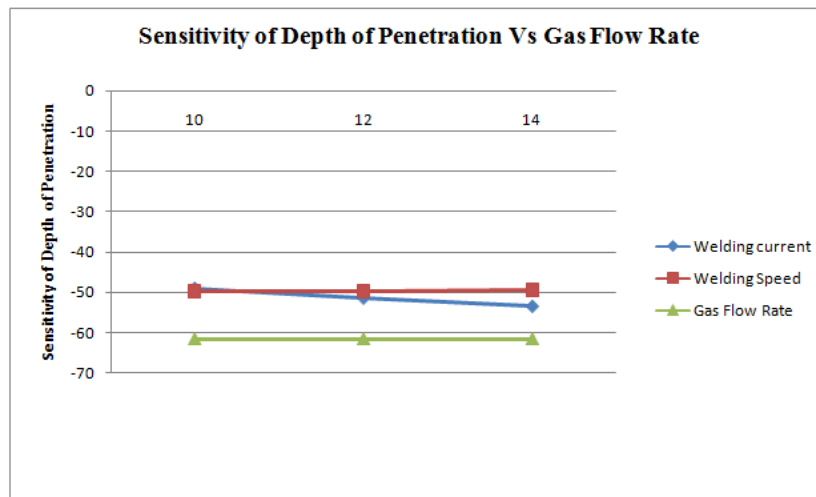


Figure 5: Shows Sensitivity of Depth of Penetration Vs Gas Flow Rate (When Current=240 amps, Welding Speed=45mm/sec)

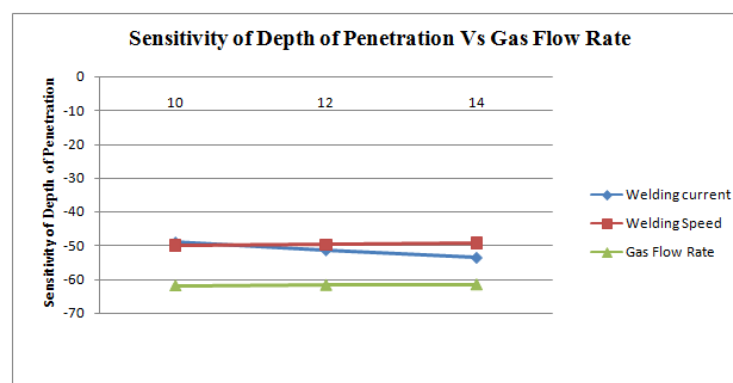


Figure 6: Shows Sensitivity of Bead Width Vs Gas Flow Rate (When Current=280 amps, Welding Speed=45mm/sec)

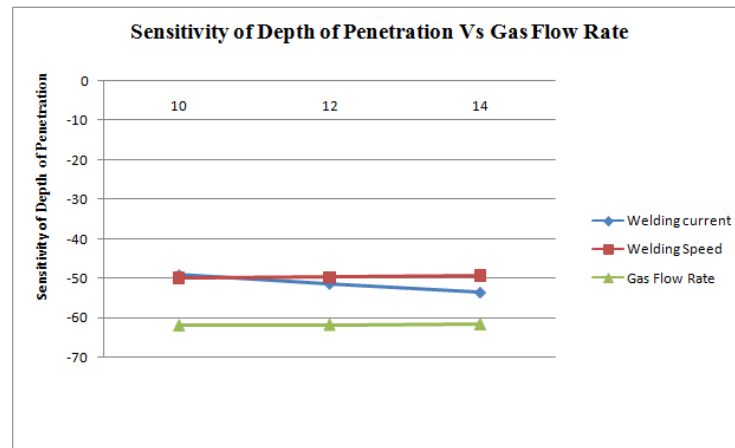


Figure 7: Shows Sensitivity of Depth of Penetration Vs Gas Flow Rate (When Current=240 amps, Welding Speed=45mm/sec)

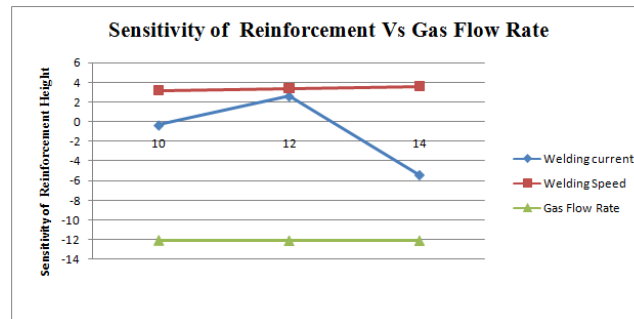


Figure 8: Shows Sensitivity of Depth of Penetration Vs Gas Flow Rate (When Current=260 amps, Welding Speed=45mm/sec)

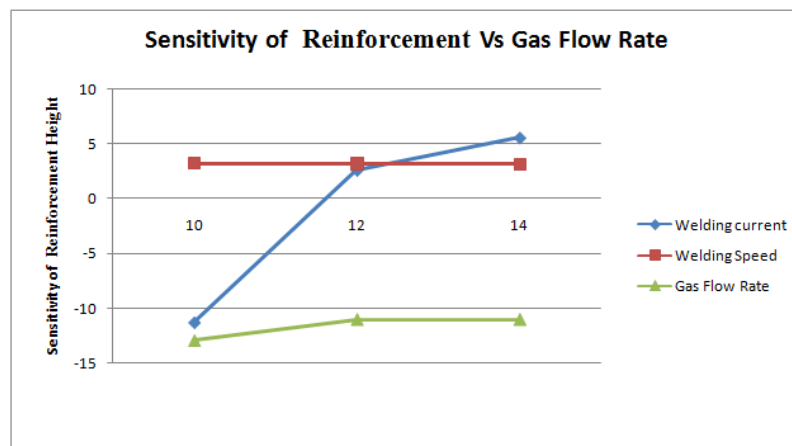
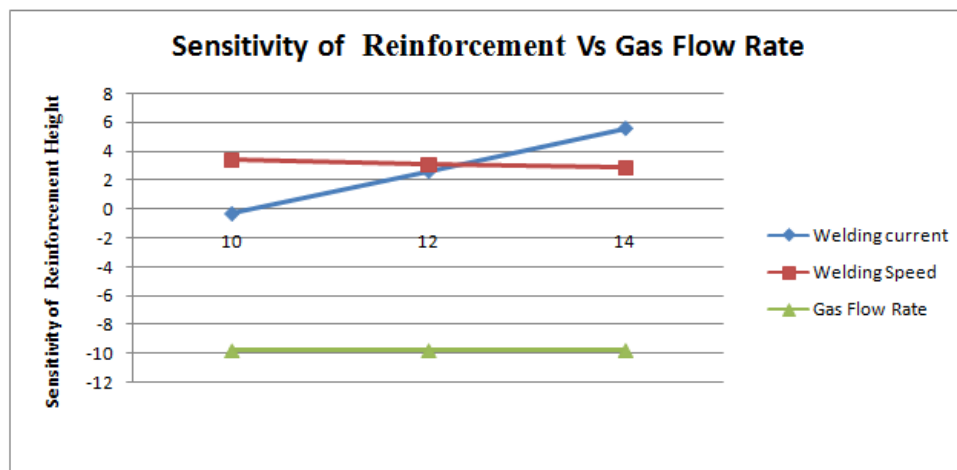


Figure 9: Shows Sensitivity of Depth of Penetration Vs Gas Flow Rate (When Current=280 amps, Welding Speed=45mm/sec)



**Figure 10: Shows Sensitivity of Reinforcement Height Vs Gas Flow Rate
(When Current=240 amps, Welding Speed=45mm/sec)**

CONCLUSIONS

In this paper, selection of process parameters using sensitivity analysis for TIG welding on ASTM- 500 GRADE B material with bead geometry was successfully analysed. Mathematical models were prepared and analyzed its sensitivity of output responses and expressed with the graphs. Following are the conclusions of the sensitivity analysis. From the sensitivity of the calculated results, the sensitivity of welding current and welding speed is positive, where the sensitivity of welding voltage is negative for bead geometry. The sensitivity of the positive value indicates that as bead width increases, welding current or welding speed increases, and the sensitivity of the negative value indicates that as bead width decreases, welding voltage increases. Mostly gas flow rate is influential for bead width. and Depth of penetration and reinforcement height is influential with welding speed.

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